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WEST INDIAN NUTRITION*

In his report entitled 'Nutrition in the British West Indies'† Dr. B. S. Platt reviews his experiences and the data he collected during a visit to those territories in 1944-45. In brief, he shows how the nature of a territory's problem may be determined by a simple and rapid clinical examination of suitable population groups, and how the value of its own food supplies in relation to human needs may be assessed. Evidence of the extent of malnutrition was obtained by clinical examination of the inmates of hospitals, institutions, etc.; by the examination of school children, and also of pregnant and nursing mothers; and by evaluation of the nutritional value of meals or of food supplies for the territory as a whole.

The clinical examination revealed no striking differences between the territories, by far the most common nutritional diseases encountered being those usually associated with a deficiency of vitamin B2. Anæmia, so severe that it was obvious even in a quick clinical examination, was frequently encountered. The incidence of gum changes of the kind usually associated with vitamin C deficiency was on the whole low, except in British Guiana, where 5 to 7 per cent. of the children were affected. The incidence of dental defects was high. Signs of rickets were rare, and there was little evidence of vitamin A deficiency—only occasionally was the follicular keratosis associated with this disease seen. The heights of the children compared favourably with those in London, but body weights were lower.

During visits to homes and markets, observations of the food eaten by groups of the population were made. Most of the population lived from hand to mouth, chiefly on account of poverty. The principal deficiency in the dietaries were B2 vitamins, especially riboflavin, calcium, and protein (in Barbados and Jamaica).

Dr. Platt goes on to show how much of this malnutrition may be reduced. All the wheat flour used in these territories is imported, and the flour should not be below 80 per cent. extraction and should in addition be fortified by the inclusion of 3 per cent. food yeast. A greater intake of calcium may be obtained by the inclusion of a calcium salt, or by the addition of 0.5 per cent. bone meal. The use of food yeast rather than specific supplement of the more

* Reproduced from *Food*, 15, 260, 1946.

† H.M. Stationery Office, Colonial No. 195, price : 9d.

purified vitamins is recommended, because the yeast will provide a supplement of the whole B complex instead of certain components only.

An estimation of the relative cost in Jamaica of a number of foodstuffs supplying riboflavin and nicotine acid showed that skimmed milk solids rank next to food yeast in cheapness, but even so cost seven times as much as an equivalent amount of food yeast. In the form of fresh milk the cost was thirteen times, and for pulses 15 times, as great as yeast.

Measures should not, however, be confined to improving the nutritional quality of the flour. The use of dried skimmed milk powder should be extended. Except for fat and the fat-soluble vitamins A and D, skimmed-milk powder contains all the nutrients found in fresh milk. At the same time the need for butterfat and associated vitamins is not so urgent in the West Indies as in more temperate climates. Fats and oils can be produced more readily from plant sources in the tropics, and the prevalence of sunshine eliminates the need for vitamin D. For supplies of vitamin A the native has rich sources at hand, such as red palm oil, green leafy materials and other vegetables such as yellow sweet potatoes. A greater cultivation of pulses and groundnuts seem desirable, taking into account their nutritional value; besides the B vitamins, they would provide useful amounts of calcium and iron.

A relatively small improvement in a foodstuff regularly and widely used often makes a more effective contribution to nutrition than what at first sight may be more spectacular measures. In so far as rice, as well as flour, is a staple food, consideration should be given to the best ways of handling to retain the maximum amount of nutritive value. To judge from past experience, some form of par-boiling would appear to offer the best solution.

Included among the short term measures for improving the diet should be the extension of good methods of cooking. The more general adoption of conservative cooking methods would do much to improve the nutritional level of West Indians.

Of the immediate economic measures that might be taken may be cited the price control of foodstuffs on the one hand, and, on the other, carefully planned facilities for collective feeding to an extent that may be necessary to ensure that a dietary of good nutritional value is within the reach of all consumers.

The foregoing remedies, as Dr. Platt emphasizes, are of an immediate nature, and further consideration must be given to long-term measures.

Facts are required on many questions before long-term measures can be taken. The basic question to be answered is, which combination of crops produced for food and export will give the best return? A balanced diet must be worked out in relation to a balanced agriculture and a balanced trade. The cultivation of improved varieties, the proper use of fertilizers and better farming methods would substantially improve the position. If, in addition, methods of modern food preservation were applied to perishable crops, these latter could be grown in the best growing season rather than, as at present, the attempt being made to produce such commodities out of season, often with total failure.

The placing of school meals on a satisfactory basis might well form the nucleus from which attacks on the wider problem might be started.

Dr. Platt's final and last suggestion, in an interesting and practical report, is that a Nutrition Working Party should be sent out to work on these problems on the spot. When the practical difficulties of providing an adequate school feeding scheme have been worked out, the party might then turn its attention to the food supply of the population as a whole.

AGRICULTURE OF BRITISH HONDURAS

In British Honduras progress in extending and improving agricultural production has been hindered by the difficulty of including the non-agricultural West Indian Creole population to practise farming instead of forestry and by the problem of replacing shifting cultivation by permanent agriculture. The topography varies from land in the north at less than 100 feet, about one-third of which is suitable for agriculture, to country reaching over 3,000 feet further south. In the extreme south there is rolling country with rich alluvium, swamps, lagoons and sandy pine ridges. Valuable mixed tropical forests and pine forests occupy 92% of the country.

Along the rivers are fairly deep, somewhat acid, fawn-grey to red-brown alluvial loams and clays. Citrus is grown in the valleys and rice on the silt near the river mouths. In the north, good, black, clayey limestone land is also found away from the rivers and in the south there is some fertile rolling limestone country with fairly rich red-brown loams. In both areas sugar is grown. Coconuts are grown on deep sandy soils along the coast and on clays off the coast.

Methods of planting maize, vegetables and tobacco amongst the Mayas are crude and there is no cultivation. The Caribs have better land and use better methods to grow cassava, plantains, sugar, rice and vegetables. The Creoles also practise shifting cultivation, but on the more fertile river banks, and grow bananas, maize and rice. There is little fertilizer used in the country.

New methods of cultivation and improvement in livestock for mixed farming are essential. Through a co-operative system it is hoped to increase food production to replace present imports of rice, beans, meat, milk and vegetables and to cultivate cassava, citrus, coconuts and bananas for export. (*Soils and Fertilizers*, 9, 253, 1946.)

THE NEED FOR SOIL SURVEYS IN THE CARIBBEAN REGION

By

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The main objects of soil surveys, as envisaged for the Caribbean Region, are to assess land resources and to lay the foundation for proper land utilisation. Soil surveys consist in the identification, description and mapping of soil-types. A soil-type is a characteristic kind of soil representing the end-product of the interaction of five chief soil-forming factors, namely, parent rock, climate, organisms (mainly vegetation), topography and time (See Appendix). It will be appreciated that these different factors vary greatly in kind and intensity within the component areas of the Caribbean Region, so that the pattern of soil-types is likely to be complicated. Nevertheless, the widespread occurrence of certain characteristic soil-groups having common features may be recognised therein by even a casual soil-reconnaissance, and it is this particular aspect that has so far chiefly concerned officers at the College. The need now is to extend and co-ordinate that work and to make the findings available to agriculturists.

Puerto Rico Survey: The most complete and detailed soil-survey within the Caribbean Region is that of Puerto Rico which has been described in a recent publication.* This goes much further than a mere description of major soil-groups and their chief chemical and agricultural features; it lists and describes 364 different soil-types arranged in 200 soil-series comprising some 25 great soil-groups. The name of each soil-type is derived from the place where it is ideally represented or was first distinguished. Unfortunately, the modern convention regarding the naming of soil-types tends to obscure their group relationships and thus greatly to perplex the agriculturist who may wish to learn from a soil-map or report the main features of the soil of his particular area. Nevertheless, the Puerto Rico Survey might serve as a model for others that may later be prosecuted, for the system of soil classification therein employed will probably prove to be generally applicable to the whole of the Caribbean Region, and by the simple expedient of using it as a basis for constructing other maps showing various aspects of soil usage, its value to agricultural enterprise will soon become evident.

Surveys of Other Caribbean Areas: Sufficient information has been published concerning the soils of some other West Indies Islands and parts of the mainland to serve as a starting point for the extension of the Puerto Rico soil survey so as eventually to embrace the whole of the Region. The need now is for the appointment of a suitably-trained field staff to do this work. The primary object would be to delineate the main soil-groups and the major soil-types that have originated through the interplay of the five main soil-forming factors named above; wherever recognisable Puerto Rican soil-types occur they should be given the chosen name in accordance with the rules of priority.

Purposes of the Soil Survey: The following are the chief aims of the soil survey.*

(i) To determine the kind, yield and quality of crop-plants that may be grown under different systems of management on various soil-types. This implies the identification and mapping of soils in the field in accordance with an accepted system of examination, description, classification and nomenclature.

(ii) To determine the chief physical, chemical and biological features of soil-types by means of field and laboratory studies of representative soil samples collected from profiles or deep sections.

(iii) To determine the responsiveness of soil-types to management (tillage, drainage, irrigation, manuring, crop-rotation, anti-erosion measures).

(iv) To determine the capabilities of soil-types under agricultural and sylvicultural usage on the basis of field and laboratory data and of actual experience on the land.

The Importance of Soil-Type in Field Experimentation: One of the chief advantages of a soil-map is that it enables the agricultural experimenter to select suitable sites for field experiments such as the testing of different varieties of crop-plants and of various soil amendments (including lime), manures (including pen manures, composts and mulches) and artificial fertilisers. Too frequently in the past, elaborate field experiments have been laid down on soil-types that later have been found to be relatively unimportant, of limited extent, or not typical of the area under consideration. In many instances, established experimental areas have been found to span a boundary between two or more different soil-types so that the applicability of results is greatly diminished or rendered invalid.

As a prerequisite to the designing of manurial experiments, the great value of soil chemical analysis and greenhouse pot-tests cannot be over-emphasised. In the case of tillage experiments, the need for a thorough knowledge of the physical features of

* Soil Survey of Puerto Rico; U.S.D.A., 1942.

* See "Soils and Men"; *Yearbook* of *Agriculture*, 1938, U.S.D.A.

soil-types examined in profile to considerable depth is evident in order that the probable effects of cultivations on water movement and soil aeration may be gauged. Similarly, in the case of drainage and irrigation experiments, since different soil-types behave differently, it is necessary to know beforehand what are the main physical features of the soil which it is proposed to treat.

The Importance of Soil-Type in Erosion Control: While it may be admitted that certain general methods of soil erosion control may be applicable to a wide range of soil-types, the choice of the most effective method for any particular area of land or kind of crop is intimately affected by soil-type (compare for example a clay soil showing severely impeded drainage *versus* an open sandy type). Thus soil-type may determine the width of the terraces necessary for soil conservation on land of a certain slope as well as the number of catchment drains that may be required.

Soil-type in relation to Soil Regeneration: The possibilities of regenerating deteriorated and eroded soils by agricultural or sylvicultural methods depends largely on soil-type, particularly the mineralogical, chemical and physical features of the soil parent material.

Thus, a parent material rich in unaltered nutrient-containing minerals (such as fresh volcanic ash) will readily regenerate a fertile soil when intensively cropped with plants that can assimilate atmospheric nitrogen (legumes), or with plants that are given nitrogenous manure so as to provide the chief missing nutrient, namely nitrogen. On the other hand, a parent material consisting mainly of heavily-leached, inert mineral residues may take a long time to regenerate and require intensive treatment with costly manures.

The Use of Soil-Maps: A soil-map is a representation of the distribution of mappable soil-units whose recognition and differentiation are based on observable external and internal characteristics. Examples of external features are steepness of slope and degree of stoniness, and of internal characters, colour, structure, texture and consistence of the several layers into which the soil profile may be sub-divided. Over areas where the profile varies but little, differences in land relief may serve for recognising mappable units. Detailed differences in chemical factors, such as phosphate content and degree of acidity, are not mappable and cannot therefore be used for distinguishing soil-units in the field, but frequently such features are closely correlated with other factors that can readily be recognised on the spot.

The soil-map, by delineating those soil areas that possess similar levels of inherent fertility and similar physical features which together decide land productivity, may be used by the agriculturist as a guide to the selection of specific cultural practices such as may have been formulated as a result of experience or scientific investigation on similar soils. In such instances therefore, the soil-map brings to the grower the findings of research.

Kinds of Soil-Map: There are three general kinds of soil-map, namely (i) the reconnaissance map, (ii) the detailed-reconnaissance map, and (iii) the detailed soil map. The first kind is based on more-or-less haphazard and disconnected observations whereas the detailed-reconnaissance map contains some part of it expressed in detail. The fully-detailed map on the other hand is based on accurate records made during systematic traverses over an area so as to include all its parts. The scale of the detailed map is generally 2 to 4 inches to the mile while that of the reconnaissance map is usually one inch or less to the mile. The time required to produce the different kinds of map and the cost of each are very different. For a great part of the Caribbean Region, the preparation of detailed soil maps is not at present necessary, but reconnaissance soil maps are urgently needed for the whole region and it is suggested that these be prepared first. In order to render their preparation possible, access to accurate topographical maps, constructed preferably from aerial photograph mozaics, is the first need.

Other Kinds of Soil-Maps: In themselves, pedological soil-maps, such as those based on the Puerto Rico soil survey, have little appeal to agriculturists or laymen who find it difficult to understand their meaning and implications. These maps may be used, however, to prepare other soil-maps or land usage maps that reveal particular features having direct practical interest, not only to agriculturists, but also to road engineers, town planners, government officers concerned in the development of peasant agriculture and the establishment of land settlements, and conservators of forests. For example, a simple drainage map, showing, say, four categories of drainage classes could readily be constructed from a pedological soil map depicting as many as 50 different soil-types. Similarly, the degree of stoniness or of profile truncation by erosion could be separately shown on simplified maps derived from detailed soil maps. The fact that a wide range of useful maps may readily be prepared from basic soil maps illustrates the complex character of the soil unit.

As an example of the use of the soil map in connection with land utilisation, the work of the Tennessee Valley Authority (T.V.A.) in the United States of America may be cited. A large number of demonstration farms have been established in the Valley; here the benefits accruing from crop rotation, practised in connection with liming and phosphating, are closely observed. The areas under different crops are carefully mapped and the crop maps are then superimposed on the soil-maps by which means soil responses may be distinguished and identified. The information

thus obtained is afterwards applied on individual farms throughout each county according to the soil-type there represented.

Productivity Ratings: Another practical outcome from the fundamental soil-map is the formulation of soil productivity ratings. The ratings naturally vary for different crops whose requirements show great divergency, being usually associated with variable features such as drainage, slope, nature and depth of soil parent material and soil lime status. Once the "ideal" soil is defined by means of laboratory researches, field experience and economic investigations, then special crop-productivity maps may readily be derived from the general soil map for each crop. Thus, in the Puerto Rico soil survey bulletin, the ratings for each soil-type, phase and land-type, according to the kind of crops generally grown, are tabulated; from these data, a crop productivity map could presumably be constructed for each particular crop. In Trinidad too, it has been found possible to prepare a productivity map showing the distribution of five different ratings for cacao, sugar-cane and coconut.

Appendix

Fundamental Principles Of Soil Genesis

Parent rocks produce different sorts of weathered material when acted upon by rain water at various temperatures. Organisms (plants, microbes and animals, including man) convert this mineral matter into humic soil. Given sufficient time and a topography that allows free drainage, mature soils, termed *Zonal*, eventually develop which are in equilibrium with the vegetation that covers them. Immature or "young" soils (such as fresh volcanic ash) are termed *Azonal* or Skeletal. Where drainage is impeded, as over flat topography, waterlogging deflects the development of zonal soils and instead *Intrazonal Hydromorphic* soils are formed. Where salts predominate, *Intrazonal Halomorphic* soils arise, and where lime occurs in abundance, as when the parent rock is highly calcareous (limestone, marl), *Intrazonal Calcimorphic* soils are produced. These main orders may be subdivided into a great number of soil-groups, soil-series and soil-types having distinctive features depending on the nature of the original parent rock, the magnitude of the rainfall, the prevailing temperature, the kind of vegetation, the land relief and the length of time during which soil formation has proceeded. All these circumstances are taken into account in soil classification.

Land Erosion continually competes with soil formation. Where erosion is so rapid that the products of rock weathering are removed as fast as they are formed, the soil is forever Azonal. Mature or Zonal soils can only develop in the absence of severe erosion. Man's misguided activities accelerate this natural or "geological" erosion.

The following statements concern the soil-forming factors operative in the Caribbean Region.

1. *Parent Rocks*: These include igneous and volcanic, metamorphic and sedimentary rocks. Practically every known kind of rock occurs. Some areas are mostly igneous and volcanic (for instance, the Lesser Antilles Volcanic Arc Islands), others are mainly sedimentary (as the Greater Antilles, Trinidad and British Honduras). Limestones and marls are particularly well represented among the sedimentary rocks (as in Jamaica and Cuba). Metamorphic rocks with igneous intrusions mainly comprise the hinterland of the Guianas of South America and the chief mountain ranges of Trinidad, Tobago and Venezuela.

The distribution and features of the main rock-types of the Caribbean Region have been investigated at various times by geologists, but no systematic geological survey has yet been prosecuted. There is fundamental need of a complete lithological survey of the whole region.

2. *Climate*: The variations in climate within the Caribbean Region are extreme. Because of the insular and mountainous nature of most of the terrain, climatic changes over short distances are rapid.

Thus, in Grenada, rainfall increases about one inch for every 10 ft. rise in altitude, and in Montserrat, one inch for every 22 ft. The highest land receives highest rainfalls up to 300 inches a year; the lowest land in some areas approaches desert with annual rainfall below 30 inches. Temperatures range from around 92 degrees F. to below 60 degrees F., depending on exposure and altitude. Hurricanes are frequent over most of the Region; they have permanently altered the vegetation of the highest lands in many of the islands, and have temporarily affected it over some flat areas.

Meteorological data for the Caribbean Region are sparse and incomplete. Too few stations have been established and the equipment of most of those in existence is inadequate for the study of soil formation and vegetational development. The absence of instruments for accurately recording winds and atmospheric evaporation (which decide the rate of soil-desiccation and of transpiration of vegetation) is particularly regrettable.

3. *Vegetation*: The natural vegetation of the Caribbean Region includes Rain Forest, Evergreen, Semi-Evergreen and Deciduous Seasonal Forests, Xerophytic Forest, Montane Forests, Litoral Forest, Mangrove, Swamp and Marsh Forests, Herbaceous and Palm communities and Savanna. In most areas, only remnants of these natural plant formations occur; some have been protected as Forest Reserves but much disastrous exploitation has gone on in the past. Second growths occupy considerable areas in some parts, particularly where "shifting cultivation" is being indiscriminately practised.

Forest vegetation surveys are now being undertaken by Forest Departments over parts of the

Region, notably Trinidad, British Honduras and the Lesser Antilles. Surveys of herbaceous vegetation in the forest and waste-places have not yet been attempted, though floras of some of the Islands have been published, for example, Trinidad (incompleted), Jamaica and Puerto Rico. There is a need for the study of vegetation succession following shifting cultivation and land abandonment.

4. *Topography*: The topography of the Region is extremely variable though altitudes are not particularly high. The maximum is about 10,000 ft. (Haiti), but the highest mountains occurring in most of the islands are seldom over 4,000 ft. The relief varies from mountainous, hilly, rolling, undulating to flat, and the surface from rugged and rough to smooth.

5. *Time*: The length of time of exposure of the parent rocks to agents of weathering within the Caribbean Region is presumably the period which has elapsed since the final emergence of the land above sea level. This event took place in the Greater Antilles, according to geologists, in Lower Pliocene times, say 10 million years ago. The land surface in many of the islands is covered, however, with superficial deposits laid down during the Pleistocene period which began three million years ago. Within the Lesser Antilles Islands, the greatest bulk of volcanic ejecta also accumulated during this period and after. Thus, soil formation in these areas has proceeded for a very great length of time, sufficient to allow of the full development of Zonal soil groups where drainage conditions have been favourable.

Soil-Types

(A) *Zonal*: The chief mature soil-groups for the region, following the recent classification adopted by the Bureau of Chemistry and Soils of the United States Department of Agriculture,* are *Grey-Brown, Yellow* and *Red Podsolic* and *Yellow-Brown and Red-Brown Lateritic,* which develop under high rainfall and high temperature from a wide range of parent rocks where the topography permits free drainage and where erosion does not too quickly remove the products of rock weathering. The majority of the Zonal soils are bright red in colour and uniform to great depth; they may conveniently be termed "Red Earth."

Under lower rainfall (below 45 ins. a year), the chief Zonal soil groups that develop are: *Reddish-Prairie* and *Reddish-Chestnut,* but these are not widespread in the Caribbean Region.

(B) *Intrazonal*: *Hydromorphic* soil-groups developed within the Region mainly comprise *Bog Soils* and *Ground-Water Soils*; these are widespread over level plains, coastal flats, deltas, estuaries and river valleys, and show variably impeded drainage.

Halomorphic (*Saline* and *Alkali*) soils are sparse; they occur only in dry coastal plains. *Calcimorphic* soils mainly comprise black crumby "humus-carbonate" soils (*Rendzina*) which are widespread in the Caribbean Region over marls and calcareous clays and are among the most naturally-fertile soils of the Islands and the mainland of Central America, for example, British Honduras.

(C) *Azonal*: Lithosols, which are very young shallow soils occurring on rocky hillslopes where erosion has kept pace with soil formation, are widespread in the Caribbean Region, particularly where land exploitation has accelerated natural erosion and has laid bare the parent rock. Thus, in Puerto Rico, Lithosols occupy nearly two-thirds of the island's surface though confined to steeply-sloping land mostly in the east. In St. Vincent and Martinique, the recent volcanic ejecta of Soufriere and Pelée, which were last active in 1902-3, have given rise to shallow stony Lithosol.

Alluvial Soils: These, in the strict sense, have been recently formed; they are "living" soils in that fresh deposits of alluvium, rich in humus, are added during each flood in the case of riverine, estuarine and deltaic alluvia, or during the rise of the tides over sea-shore flats in the case of coastal alluvium. Alluvial soils are among the most productive in the Caribbean Region. They mainly comprise fertile sugar-cane lands, for example, over the coastal flats and along river flood-plains in Puerto Rico, Jamaica, and other islands of the Greater Antilles, and in British Guiana.

Soils of the Volcanic Islands:* The pedological relationships and exact classification of the soil-types derived from fragmental volcanic ejecta comprising the greater part of the Lesser Antilles have not yet been settled. Comparable soils do not occur in Puerto Rico so that such soils were not described nor discussed in the recent survey bulletin. Certain of the chief Zonal, Intrazonal and Azonal soil-groups mentioned above can easily be recognised among them, however, for example, Zonal *"Red Earth"* in the oldest, highest and wettest parts, Intrazonal Hydromorphic *"Shoal Soil"* and *"Terras Soil,"* Intrazonal Calcimorphic *"Yellow Earth"* and *"Brown Earth,"* and Azonal Lithosols, such as *Fresh Volcanic Ash Soil* already mentioned. Finally Azonal *Alluvial Soils,* although prevalent in the Volcanic Islands, are nowhere conspicuous nor agriculturally important.

* See "Soils and Men"; *Yearbook of Agriculture,* 1938, U.S.D.A. Also "Soil Survey of Puerto Rico;" U.S.D.A., 1942.

* The provisional names here given to the soils of the Caribbean Volcanic Islands are subject to substitution by other names that might be agreed upon by soil surveyors when the soils of the Caribbean Region are considered as a whole.

THE SIGNIFICANCE OF CARBON-NITROGEN RATIO IN SOILS GROWING COTTON

(III) Nitrate Fluctuations in Relation to Planting Date and Soil Manurial Requirements in the British West Indies

By F. Hardy,

(Imperial College of Tropical Agriculture, Trinidad)

(I) Introduction

In Part I of this article, evidence was adduced from chemical analyses of typical Queensland cotton soils to demonstrate that "bolting" (that is, the development by the cotton plant of rank, sappy, unfruitful growths, susceptible to insect attack) usually occurs on soils that have relatively low carbon-nitrogen ratio, whereas normal healthy plants are produced on soils that have high ratio. The reason for bolting has been traced to an excessive rate of formation of nitrate under certain moisture conditions. Soils having this feature generally comprise "old" cultivations, particularly where the soil-type is Red Earth or Black Earth. They usually give, on incubation under ideal conditions in the laboratory, nitrate-nitrogen values ranging from 30 or 40 p.p.m. up to or above 50 or 60 p.p.m. On the other hand soils that produce amounts of nitrate less than 40 or 30 p.p.m. generally comprise "new" lands recently under forest or scrub or freshly brought in from pasture or grassley; they are mostly rich alluvial soils. The critical carbon-nitrogen ratio for Queensland cotton soils seems to lie between 7.0 and 8.5.

When these principles were applied to the soils of the chief British West Indies cotton-growing islands which have been extensively chemically analysed in the past, it was found that relatively high nitrate production occurs generally in soils whose carbon-nitrogen ratios lie above 10.5. These soils conform to the "old land" category but their critical C/N ratio is evidently higher than it is for the soils of Queensland. This may perhaps be explained by the wetter climate.

The more important features and distribution of the main soil-types of the four chief British West Indies cotton-growing islands have been described in Part II of this article* and brief comparison has therein been made between them and the cotton soils of Queensland and those of the South-Eastern United States of America. With the object of trying to correlate the nitrate-producing capacity of the West Indies soils and the physiological behaviour of the cotton plants growing in them with their nutrient status and manurial needs, the rainfall regimes within each of the insular areas has also been described in Part II and compared, with particular regard to total amount of rainfall, monthly distribution of rain and rain-shower category. In the following account it is proposed first to consider in further detail the nitrate fluctuations in the British West Indies cotton soils and afterwards to discuss their physiological and agricultural relationships with the cotton crops grown on them, and finally their manurial requirements.

The future success of the Sea Island Cotton industry in the British West Indies depends mainly on improvement of yield, and this can only be attained by improved farming methods including the greater use of artificial manures.

To quote from a recent summary† of the present condition of the industry by the Cotton Adviser :—

> "In the past, the greater part of the technical assistance "given to the Sea Island industry has been devoted "to the improvement of the varietal situation and to "pest control, and it is in consequence of the success "of this work that seed supply and pest control are "now largely routine matters. Yield improvement by "cultural methods has not received the same attention, "but enough has been done to show on the one hand "the crying need for better farming systems and on "the other the great opportunities that exist for agri-"cultural betterment."
>
> "The explanation of the possibilities of improved "yields by better farming depends on the extension of "present knowledge of West Indian soil-types, their "rehabilitation where they have been eroded, their con-"servation and amelioration, by suitable cultivation "methods and their improvement with organic and "mineral manures."

(II) Nitrate Fluctuations in West Indies Cotton Soils

From information obtained by actual measurements on sandy soil comprising field plots at the College,* it appears that, when the amount of evaporation exceeds the rainfall, nitrate begins to accumulate in the topsoil, provided there is no actively growing crop present to utilize it. This is likely to take place when the mean monthly rainfall drops below 4.0 ins. and it definitely seems to occur when the monthly rainfall is below 2.4 ins.

> The actual numerical data for fallow plots indicated that, in cases where the fluctuating nitrate content of the topsoil showed an upward trend accompanied by a fall in soil moisture content, the rainfall of the previous 28-day period was below 4.0 ins. though mostly below 1.8 ins. On the other hand, where it showed a downward trend, accompanied by a rise in soil moisture, the previous 28 days' rainfall was above 3.6 ins. and mostly above 6.7 ins. The highest value for accumulated nitrate-nitrogen in the College fallow-plot soil was 63 p.p.m. which is equivalent to a dressing of about 5½ cwt. of sulphate of ammonia per acre 6-ins. of soil, and shows an accumulation of nitrate over and above the incubation value (30 p.p.m.) equal to about 2½ cwt. per acre of sulphate of ammonia.

If we accept the generalisation that, for months having rainfall less than 2.4 ins., nitrate is likely to

* The Significance of Carbon-Nitrogen Ratio in Soils Growing Cotton : (II) The Soils and Climates of the British West Indies Cotton-Growing Islands. F. Hardy, *This Journal*, 1946, 23, pp. 178-189.

† The Agricultural Problems of the West Indian Cotton Industry. J. B. Hutchinson, *Rept. of 8th and 9th Meetings*, 1944, W.I.S.I.C.A., p. 13. Reproduced in *This Journal*, 1944, 21, pp. 121-123.

* Seasonal Fluctuations of Soil Moisture and Nitrate in a Humid Tropical Climate (Trinidad, B.W.I.) : F. Hardy, *This Journal*, 1946, 23, pp. 40-49.

accumulate in considerable quantities within the rooting zone of the cotton plant, provided C/N ratio is suitable, whereas for months having rainfall above 4.0 ins. it is likely to be removed by downward leaching, then certain characteristic differences between the West Indies cotton-growing islands and between these and the cotton-growing areas of Queensland and of the South-Eastern United States, are clearly revealed. For example, St. Vincent stands out from the rest of the four chief cotton-growing islands in that it seldom experiences in an average year more than one dry month having total rainfall less than 2.4 ins. and in the wettest parts usually none. In this respect it resembles the S.E. States although the total rainfall there is much less. At the other extreme, Nevis experiences in an average year 2 or 3 dry months. In comparison, Montserrat and St. Kitts have only one or 2 dry months and may thus be considered intermediate. Of the less important cotton-growing islands, Barbados and Carriacou have 4 dry months, Antigua 3 though sometimes up to 6, and Union 5 dry months. By contrast, the cotton-growing region of Queensland has 8 dry months per year though the total rainfall is about the same as that of Union Island. Year to year variation for all these places is large but its degree is unpredictable.

As a general rule, therefore, nitrate would not be expected to accumulate in the soils of the wetter parts of St. Vincent, Montserrat and St. Kitts, except in abnormal years when the dry season is more marked than usual, whereas it would regularly be expected to accumulate in the soils of Nevis as well as in the soils of Barbados, Carriacou and Antigua, and particularly Union.

These differences ought to be recognisable in the variable nitrogen nutrition of the cotton crop grown in the different islands, as well as in different parts of each island. They should also be reflected in the differential response to nitrogenous manures. The practical importance of these aspects of the subject is indicated by the relatively large magnitude of the nitrogen accretions that may be involved.

It is interesting to note in this connection that Mr. H. L. Manning, Cotton Research Officer in St. Vincent, (private communication from Mr. J. B. Hutchinson, Cotton Adviser) found a significant negative correlation (-0.73 with n = 10 and p less than 0.01) between the actual yield of cotton lint per acre in St. Vincent and the amount of rainfall during the dry season months, April, May and June, previous to the date of planting, for the years 1930-40. The yield data were those of the variety V 135 (Sea Island Cotton) and the rainfall data appertain to two stations in each of three districts, leeward, windward and south (Kingstown). The mean monthly rainfalls during the 3-months' periods ranged from 7.67 to 3.14 ins.; the mean for April was 2.30, for May, 5.51 and for June, 8.59 ins. Yields above the mean (i.e.: over 115 lb.) were obtained in years when the mean rainfall for April, May, and June were 2.51, 4.10 and 7.82 ins. respectively. These data suggest that nitrate accumulation may have occurred in the previous dry season and to a greater extent during years when the yields were relatively high as compared with years when they were low.

(III) The Agricultural Significance of Nitrate Fluctuations in Cotton Soils

Physiological growth phenomena: In most of the West Indies cotton-growing areas, the cotton crop is planted in August, September or October. The bolls are set during the early drying months and ripen during the dry season. The plant thus matures under conditions of diminishing humidity and the sequence of vegetative growth and reproduction is normal. In the S.E. States, cotton is planted in April or May as soon as day temperature has risen above 60° F. This period corresponds in the monthly rainfall sequence to September or October in the West Indies. In Queensland, cotton is planted in February or March, corresponding with August or September in the West Indies. On the other hand, in Montserrat and St. Kitts, cotton is usually planted in February, March or April as soon as favourable rains occur. The crop then develops under increasing humidity; the sequence of growth phases is abnormal and, unless fruiting is well established before the onset of the heavy rains, the plants may "bolt" and the young fruits may suffer destruction by fungous diseases or they may be shed. In extreme cases, physiological disturbances, for example, "loggerhead" and "chibble leaf," may render the fruiting branches completely sterile.* Such physiological upsets are particularly frequent in cotton growing on Shoal soil in Montserrat though not in cotton growing on Shoal soil in Nevis, but it should be noted that the planting season in Nevis, as in St. Vincent, is August to October.

The various growth phenomena may readily be explained in terms of nitrate fluctuations. When cotton is planted in the middle of the *wet season*, the available nitrogen content of the soil is likely to be at its lowest level. Any excessive amounts of nitrate that might have accumulated during the previous dry season may have been leached out and lost. Nevertheless sufficient nitrate may be continuously formed in the soil to meet the increasing demands of the growing crop as the wet season advances, but this presupposes that the soil's store of total nitrogen is adequate and that suitable conditions for nitrification obtain throughout the vegetative phase of the crop's growth. There may thus always be a sufficient, though not an excessive, supply of nitrate, and, provided available phosphate and potash are also present in adequate amounts, normal development may proceed. For soils deficient in total nitrogen, and for soils having excessively free drainage, the value of a surplus of nitrate accumulated during previous dry months may be considerable in that it will augment the supply made available during the early growing season.

When cotton is planted in the middle of the *dry season* as in Montserrat and St. Kitts, the nitrate status of the soil during the early growth of the crop may be relatively high through previous progressive accumulation. If the subsequent rainfall is sufficient though not excessive, vegetative growth

* J. B. Hutchinson; *ibid.*, p. 13.

may proceed normally, but if the soil drainage is seriously impeded, then the superabundance of nitrate, accompanied by a high soil moisture status, may cause vigorous growth resulting in bolting or the appearance of physiological affections. Thus the impeded-draining Terras and Shoal soils of the wet central leeward district of Montserrat frequently produce cotton plants that exhibit these abnormal phenomena when the planting season is early although they do not generally show them when the crop is planted late.

The physiological vegetative behaviour and the yielding capabilities of the cotton-crop in the British West Indies are thus mainly determined by four important factors, namely —

(1) The nitrate-producing capacity of the soil, as decided by total nitrogen content, C/N ratio, reaction (pH value) and micro-organic population.

(2) The intensity and distribution of the rainfall, expressed broadly by the number of dry and wet months in the year.

(3) The permeability of the soil which decides the degree of freedom of drainage and the amount of leaching.

(4) The date of planting.

The interrelationships between the first three of these factors are different and characteristic in the various cotton-growing areas, although a much fuller knowledge of their variability is needed before the selection of the best planting dates could finally be made. Such knowledge may only be obtained by intensive investigations of cotton soils in the field, augmented by detailed soil surveys and the systematic collection of meteorological data, and supported by a large number of field experiments. Nor are these three the only deciding factors; many other circumstances are also involved in the growth and yield of the cotton crop, for example, the phosphate and potash status of the soil, as well as the degree of insolation (which decides environmental temperatures and the amount of incident light) and also winds and hurricanes, and the prevalence of insect pests and fungous diseases.

Nutrient relationships and the effects of manuring: The nitrate status of the soil is only one of the chief nutrient factors concerned in growth and reproduction for it is well known that the uptake and utilisation of available nitrogen is largely "conditioned" by the phosphate and potash status of the soil, as well as by its moisture content.

> In a recent unpublished paper entitled "Studies on the mineral nutrition of the cotton plant in relation to climate," Dr. E. Phillis * states that, for a low level of nitrogen supply, much greater growth is obtained under wet shady conditions in pot cultures in the greenhouse than under dry sunny conditions; also that more nitrogen (and phospate) is needed to give maximum dry weight production under dry and sunny than under wet and shady conditions. The reverse holds for potash which therefore serves as "an insurance against sunless summers." There would thus appear to be no need to attempt to correct a small nitrogen deficiency if wet weather is anticipated. Under a low nitrogen supply, the cotton plant experiences difficulty in absorbing and utilising soil moisture and responds by producing a

* Privately communicated. See also, Progress Reports from Experiment Stations, *E.C.G.C.*, 1942-3, p. 173.

TABLE 1

Comparative Nutrient Status Of Chief Soil-Types

	Area cultivable $\times 10^3$ acres	Percent. of cultivable area %	C/N ratio	Total N %	Probable available nitrogen (NO_3) p.p.m.	Avail. phosphate (P_2O_5) p.p.m.	Avail. potash (K_2O) p.p.m.
ST. VINCENT							
1. Alluvial-Colluvial	2.3	5.2	10.8	.116	40	135	260
2. Lithosol	7.2	16.4	11.3	.109	40	80	130
3. Yellow Earth	25.3	57.9	10.7	.145	50	15	240
4. Terras and Shoal	9.0	20.5	9.4	.130	45	15	86
MONTSERRAT							
1. Alluvial-Colluvial	0.2	1.0	10.6	.074	25	200	250
2. Lithosol	2.1	10.7	11.0	.092	30	220	230
3. Yellow Earth	1.7	8.7	10.9	.120	40	90	150
4. Brown Earth	4.4	22.4	10.8	.120	40	60	160
5. Rendzina	—	—	11.1	.180	60	50	190
6. Terras	0.7	3.6	10.0	.170	60	65	260
7. Shoal	10.5	53.6	10.8	.170	60	30	130
ST. KITTS							
1. Lithosol	15.2	63.6	10.9	.134	45	50	140
2. Yellow Earth	7.4	30.9	13.1	.115	40	40	120
3. Shoal	1.3	5.5	10.9	.120	40	60	70
NEVIS							
1. Lithosol	4.6	20.0	11.7	.150	50	20	120
2. Shoal	18.4	80.0	12.1	.150	50	15	110
WEIGHTED MEANS	—	—	10.9	.125	40	—	—

larger root system and diminishing its degree of foliar hydration, causing the plant to become stunted. Under dry and sunny conditions, increase of available soil phosphate causes a further decrease in the uptake of nitrogen (and also potash). It was established that the yield of cotton is mainly decided by the amount of nutrient uptake during the first three months' vegetative growth. When fruiting begins, nutrient uptake is severely checked.

In Table I, approximate contents of available nitrogen, phosphate and potash for representative West Indies cotton soils are presented for the purpose of indicating their probable manurial needs. They have been taken from the large mass of accumulated laboratory data obtained during reconnaissance soil surveys of the Islands.

The relative importance of each soil-type in each island is first indicated in Table I by the acreage of cultivable land and as percentage of the total area each occupies. The characteristic C/N ratios and the mean total nitrogen contents are next given, from which the probable nitrate status is derived by multiplying by the mean nitrogen-conversion factor, 34, deduced in Table V of Part II of this article. Next, the approximate mean available phosphate contents are given, based on results obtained with the Truog chemical test, and also the approximate mean available potash contents (expressed as exchangeable potash) are presented. For interpreting the experimental values, the following arbitrary scheme may be applied to the data.

Category	*Total Nitrogen (N)*	*Nitrate (NO3)*	*Phosphate (P2O5)*	*Potash (K2O)*
	%	p.p.m.	p.p.m.	p.p.m.
1. High	0.30-0.20	100 - 70	120 - 75	360 - 240
2. Medium-high	0.20-0.15	70 - 50	75 - 50	240 - 160
3. Medium	0.15-0.10	50 - 35	50 - 35	160 - 120
4. Medium-low	0.10-0.07	35 - 25	35 - 25	120 - 60
5. Low	0.07-0.01	25 - 5	25 - 5	60 - 10

The data in Table I indicate wide variation in the nutrient status of the different soil-types as developed in the different islands. It should be possible however to predict therefrom the physiological behaviour of the cotton crop in each area under its peculiar climate, and to suggest the chief manurial needs of its soils. This information should serve as a useful guide to future manurial experiments whereby increased production of cotton may eventually be obtained through the application of the field results. *Discussion*: (i) *Nitrate*. Each of the soil-types represented in the four chief cotton-growing islands possesses only a medium or border-line capacity for producing nitrate under ideal conditions of nitrification, although amounts of nitrate in considerable excess of the recorded values may accumulate under favourable conditions during dry weather, say up to twice these quantities. Lowest nitrate-producing capacity is shown by the *Alluvial, Colluvial* and *Lithosol* (recent volcanic ash) soils of Montserrat and St. Vincent which have only medium to medium-low contents of nitrogen and exhibit also the freest drainage. These soils would therefore be expected in theory at any rate, to respond readily to nitrogenous manures both when planted in the wet season when nitrate supply is lowest because of leaching, and when planted in the dry season when nitrate utilisation is least owing to the sunny weather. The relatively very wet climate of St. Vincent would be expected to favour the rapid loss of nitrate by leaching so that nitrogenous manures should be particularly efficacious in that island.

Highest nitrate-producing capacity is shown by the *Rendzina, Terras* and *Shoal* soils of Montserrat and Nevis which have medium-high total nitrogen contents and also exhibit impeded drainage. These soils would not therefore be expected in theory to respond to nitrogenous manures, especially when planted in the dry season because of their high nitrate status. Indeed, under dry conditions these heavy soils might produce too much nitrate, so that the physiological disturbances which are known to affect cotton plants growing on these soils, might bring about a serious reduction in crop yield. When planted in the wet season, they may not respond to nitrogenous manures either, because their drainage impedence would prevent the total removal of nitrate though it might not allow a surplus to remain sufficient in amount to cause bolting or to bring about physiological disturbances.

The behaviour and response to nitrogenous manuring of the other soil-types may be regarded as intermediate between those of the extreme cases; each should be considered on its merits. Perhaps the main feature of the laboratory data for nitrate-producing capacity is their great variability, even within any one soil-type, although a strong tendency for the nitrate status to be highest in the impeded-drainage soils is very evident. This factor of variability precludes the acceptance of strict generalisations regarding the nitrogenous manuring of cotton soils in different parts of the British West Indies beyond the conclusion that its need is universally indicated; precise quantitative relationships can only be established by careful experimentation in the field.

(ii) *Phosphate*: The available phosphate (Truog) values range from very high for *Alluvial, Colluvial* and *Lithosol* soil-types occurring in St. Vincent and Montserrat, to very low for *Shoal* soil in St. Vincent, Montserrat and Nevis. The high values obtained by the chemical test for Lithosol (recent volcanic ash soil) appear to be abnormal since pot-tests with Sudan Grass as indicator, applied to St. Vincent Lithosol (Soufriere), have shown marked responsiveness to superphosphate manure.* Tests have also demonstrated, however, the pronounced normal deficiency of available phosphate in certain Yellow Earth and Terras soils from St. Vincent. On the

* Subsoil Fertility of Eroded Volcanic Ash in St. Vincent, B.W.I., F. Hardy and E. G. Cripps. *This Journal*, 1944, 21, pp. 30-39.

whole the data for phosphate show great variability just as in the case of nitrate and it would appear that each of the soil-types represented in the West Indies volcanic islands may show an actual deficiency in available phosphate in many instances, depending partly on the degree of erosion. The depressing effect of phosphate deficiency on cotton yields is likely to be especially marked (according to Dr. Phillis' results) under dry sunny conditions. If, however, phosphatic manures are employed to make good the deficiency, extra nitrogen and potash might also be required since, under these same circumstances, the uptake of nitrogen and potash is said to be diminished when the amount of available phosphate is increased.

(iii) *Potash*: A remarkable feature of the data in Table I is that nearly all the soil samples show adequacy of potash supply. The only soil-type that tends towards potash deficiency is *Shoal*. It is also noteworthy that the soils of St. Kitts-Nevis on the whole seem to contain less available potash than those of St. Vincent and Montserrat. As before, however, the data are very erratic so that strict generalisation is unwarranted. In view of these facts, the value of potash manure in cotton production in these West Indies cotton-growing islands seems to be doubtful, or at least of much less account than that of nitrogen and phosphate manures. It does not necessarily follow, however, that when nitrogenous and phosphatic manures are more widely used in cotton cultivation in the British West Indies, potassic manures may still not be required. On the contrary, according to Dr. Phillis' findings, potash manure may eventually prove to be of considerable value, especially during cloudy and wet growing-seasons when its presence may enhance the uptake and utilisation of both nitrogen and phosphate.

(IV) The Bearing of the Results of Manurial Experiments on Cotton Cultivation in the British West Indies

St. Vincent

Manurial experiments in St. Vincent have been carried out almost continuously since 1912 with great improvement in technique in recent years. Prior to 1929, the planting date was June, coincident with the advent of the wet season, but afterwards it was changed to September so that ripening could take place in dry weather. The manurial experiments have been mostly carried out at the experiment station near Kingstown where the soil-type is chiefly *Coastal Alluvial* and the rainfall very high and continuous. This soil-type has also been tested, however, at some other places. A few experiments have been tried elsewhere on *Colluvial* soil and some have been laid down on hillslopes presenting more-or-less eroded phases of *Yellow Earth, Terras* and *Shoal* showing variable drainage impedence. In no case has chemical soil-analysis been employed as an aid to the selection of suitable kinds and qualities of manures to be applied.

The early results for *Coastal Alluvial* soil (mainly obtained by Dr. S. C. Harland) proved conclusively that "the element most necessary is potassium," and that "the size of the crop is limited by the supply of potash in the soil," although it was admitted that "a lack of nitrogen is already becoming seriously felt." The finding that potash manure produces greatly increased yields may be explained on the supposition that, when the rains break in June, the soil probably contains an appreciable store of accumulated nitrate* which is taken up in greater amount and utilised all the more effectively when potash is plentiful, especially under the wet cloudy conditions that generally obtain in most of the cotton-growing districts of St. Vincent during the early wet season.

The later results (mainly obtained by Messrs. S. H. Evelyn, A. K. Briant, C. K. Robinson and H. L. Manning) for the same soil-type, as well as for others, proved equally conclusively that "inorganic nitrogen provides the greatest single stimulus to growth and yield," and that the potash effect is noticeable only on eroded land. It should be noted, however, that these later experiments were carried out with cottor sown in the middle of the wet season.

The discovery that nitrogenous manures give greatly increased yields on several soil-types in St. Vincent with September-sown cotton may be explained by assuming that any store of nitrate that might have accumulated in the soil during the previous dry season will have been more-or-less completely dissipated and lost through leaching before the crop is planted. There may then be an acute shortage of available nitrogen which could only be made good by the addition of nitrogenous manure.

In one of the latest experiments (H. L. Manning 1942-43), compost (chemically analysed at the College) was tested against artificial manures having approximate chemical equivalence with respect to the total contents of nitrogen, phosphate and potash. The soil was a deeply-eroded phase of *Yellow Earth*. It was found that the nitrogen content of compost was not so "effective" as that of sodium nitrate, so that the equivalent artificial manure mixture gave considerably larger yields when one-third of it was applied a week before sowing and the rest 6 weeks after. Striking differential responses to manurial treatment were shown by three different varieties of Sea Island cotton.

Phosphatic manure has failed so far to give any significant response in the manurial experiments on cotton in St. Vincent, even on phosphate-deficient eroded Yellow Earth soil. This may be owing to the fact that the dosages used were too small, being generally less than 300 lb. ac. of superphosphate.

Montserrat

Between 1910 and 1929, manurial experiments on cotton in Montserrat mainly consisted of trials of pen-manure, cotton-seed meal and green dressings with

* This suggestion seems first to have been put into concrete form, as far as conditions in St. Vincent are concerned, by Mr. H. L. Manning who expounded it to the writer in October, 1940.

and without artificial manures added in nominal amounts. * The results obtained showed little advantage in manuring and the subject received small attention from planters. The chief recommendation was that the "supply of humus in the soil be maintained."

Between 1929 and 1940, few manurial experiments seem to have been carried out; those that were proved to be abortive, generally because of damage by insect pests or because the increases in yield were insignificant, and the results were therefore not published.

In 1940, a manurial experiment on *Brown Earth* soil was laid down (by W. R. E. Nanton) in which, for the first time, yield results were interpreted on the basis of chemical analysis of the soil-type. † The results obtained are indicated in Table II. They show marked responses to ammonium sulphate and to superphosphate on a soil previously recorded as deficient in total nitrogen and in available phosphate.

In 1941, a larger experiment was laid down (by W. R. E. Nanton) on *Lithosol* and *Shoal* soils. The results are also summarised in Table II. They indicate a marked response to ammonium sulphate and to superphosphate by *Lithosol* shown by chemical analysis of the control plots to be deficient in total nitrogen but apparently not deficient in available phosphate as measured by the Truog chemical test. It had, however, previously been shown by pot-tests at the College that Lithosol (fresh volcanic ash) shows marked phosphate deficiency to indicator plants such as Sudan Grass and Tomato. One of the *Shoal* soils which was markedly deficient in available phosphate according to chemical test, but not deficient in total nitrogen, gave an appreciable response to superphosphate but no response to ammonium sulphate.

In 1942, a still larger experiment was carried out (by W. R. E. Nanton) on *Lithosol, Alluvial, Brown Earth* and *Shoal* soils occurring in different parts of the Island. As before, soil samples from the control plots were chemically analysed at the College. The results (in Table II) again agree reasonably well with the chemical data. Thus, *Lithosol,* deficient in total nitrogen, gave a big response to ammonium sulphate but did not respond appreciably to potash and phosphate manures. The last result is unusual, since recent volcanic ash soil, though giving high phosphate values to the chemical test, generally shows deficiency when examined by pot-tests. *Alluvial* soil, resembling Lithosol, gave similar results. *Brown Earth,* where deficient in the major nutrients, gave proportionate responses to the corresponding artificial manures. *Shoal* soil, fairly well supplied with nitrogen though very deficient in phosphate and somewhat deficient in potash, gave small response to ammonium sulphate and very little response to potassium sulphate but large response to superphosphate.

In 1943, similar comprehensive experiments were laid down on different soil-types but adverse weather and insect damage destroyed most of the crops and the test was a complete failure.

Discussion: The planting dates (fixed annually by legislation) for the above-mentioned experiments varied between March and April. As is usual for Montserrat, the succeeding weather was extremely variable both between successive months and in the different years. It was favourable during the growing season of 1940, but unfavourable in 1941, being excessively rainy during May. In that year a large response to nitrogenous manures was given by *Lithosol* but not by *Shoal* soil. Cotton plants growing on a plot of Shoal sown a month later than the others developed "chibble," a physiological abnormality typical of Shoal soil in Montserrat in wet years. These facts indicate heavy nitrate leaching in the Lithosol and retarded removal in the Shoal. The weather following sowing in March, 1942, was dry, necessitating considerable replanting in April. Wet weather occurred throughout July, causing shedding and the spread of pests and diseases. Large and highly remunerative response to nitrogenous manure was again given by *Lithosol* and by *Alluvial* and *Brown Earth* soils, all of which have a relatively low capacity for producing nitrate. *Shoal* as before gave only small response to nitrogenous manure; a mild form of chibble developed on some of the nitrogen-treated plots on this soil-type.

The effect of date of sowing on the development and yield of cotton was specifically investigated (by W. R. E. Nanton) in 1942 and 1943. Earlier unpublished work (by S. A. Schouten) in 1938 had shown "a rapid and regular falling-off in total fruiting material" as the sowing date was set later in the year and the 1942-43 investigations similarly showed a very large diminution in lint yield between crops sown in March, April and May. In 1943, the March-sown plants received adequate rain; they flowered in late July and ripening was prolonged. Pests and diseases were rare. The April-sown plants developed their fruits in rainy weather and boll diseases and pests were prevalent in September. The May-sown plants were also affected by the wet August weather; much boll shedding occurred and pests and diseases were rampant in the reaping season. It was suggested that the main reason for the superiority of the March-sown crop was a high "level of available nitrogen at sowing time."

Effect of Variable Rainfall: The relationship between rainfall and cotton yields in Montserrat is especially stressed in the Annual Reports of the Department of Agriculture for 1936, '37, '38, where evidence is adduced in support of the contention

* Annual Reports of Agricultural Department, Montserrat, B.W.I.

† The writer is indebted to Mr. J. B. Hutchinson, Cotton Adviser, E.C.G.C., for information on the results of these experiments and of others carried out in Montserrat and Nevis described later in this article.

that "the distribution of rainfall (in Montserrat) at critical periods in the development of the crop is the primary factor influencing yield." The yields obtained in 1934 and 1935 were particularly high. The seed was sown in March to May in each of these years. Good but not excessive rains fell during the four-months' growing period and the reaping period was not excessively wet. By contrast, the yields obtained in 1936, 1937, and 1938 were poor. Planting was carried out in 1936 over a lengthy period (February to June) because March and April were particularly dry whereas May and June were unusually wet. The growing and reaping periods were also very wet and boll diseases were prevalent. Similar weather to this prevailed

TABLE II : SOILS OF MONTSERRAT : RELATIONSHIP BETWEEN RESULTS OF MANURIAL EXPERIMENTS AND CHEMICAL ANALYTICAL DATA FOR PLOTS ON DIFFERENT SOIL-TYPES.

(Data for composite soil samples from no-manure plots, top 6-ins. layer)

Control plots.	Soil type	Index of text. (I.T.)	C/N ratio	Total N %	Probable nitrate (NO3-N) ppm.	Avail. phosphate (P205) ppm.	Avail. potash (K20) ppm.	Result of manurial experiments.
					1940 Experiment			
Wh.	Brown Earth	7	12.6	.110	37	36	227	S-A 12% increase ; Super 9% ; Potash none
					1941 Experiments			
R. 1.	Litho	0	12.0	.076	26	213	191	S-A 29% increase ;
2.	-sol	0	11.2	.069	23	225	190	Super 11% ;
3.	„	0	11.3	.067	23	290	211	S-Pot nil
E. 1.	Shoal	21	10.5	.217	74	876	1268	Only slight response to any manure
2.	„	22	9.7	.182	62	175	888	
3.	„	15	10.4	.223	76	26	343	Super appreciable increase ; S-A, S-Pot nil
					1942 Experiments			
R.	Litho	0	12.7	.076	26	132	140	S-A 30% and 49% increase ;
B.	-sol	0	11.4	.072	24	157	467	Super and S-Pot nil
OG.	„	10	12.8	.127	43	127	600	No increase from any manure.
O.R.	Alluvial	0	11.4	.085	29	227	144	Damaged ; no results
Tr.	„	0	14.7	.074	25	80	501	NaN03 60% increase ; Super slight ; M-Pot nil
B.F.	„	0	12.0	.059	20	320	109	Damaged ; no results
A.	Brown Earth	6	11.7	.111	38	53	107	Damaged : no results
Tu.	„	7	12.8	.124	42	38	111	M-Pot 17% increase S-A 10% ; Super 5%
T.R.	„	5	11.4	.107	36	78	200	S-A 40% increase ; Super 2% ; M-Pot nil
P.	„	0	11.5	.091	31	113	179	S-A 12% increase ; Super 69% ; S-Pot nil
E.	Shoal	9	12.1	.123	42	123	413	Damaged : no results
O.R.	„	12	12.4	.171	58	23	90	Super 40% ; S-A 11% increase M-Pot slight
WW.	„	10	12.4	.161	55	53	222	Spoilt

NOTE : (1) Values in **black** denote deficiencies
(2) *Provisional limits of adequacy* for cotton :—
Total nitrogen, 0.120 per cent.
Nitrate, 40 p.p.m. (Incubation test)
Phosphate, 40 p.p.m. (Truog test)
Potash, 140 p.p.m. (Exchangeable potash).

in 1938. In 1937, the season started well but June and July were dry so that growth was retarded. The monthly rainfall data for the years in question are given in the following table :—

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	3 mths Planting Mar-May	4 mths Growing May-Aug.	Reaping Sep.-Oct.	Total.
1934 ..	4.9	1.9	4.1	0.9	3.3	3.9	5.5	8.4	4.1	2.5	10.6	7.3	8.3	21.1	6.6	57.4
1935 ..	1.7	2.1	3.1	2.8	3.8	5.4	5.0	4.4	5.5	8.1	7.7	4.6	9.7	18.6	13.6	54.2
1936 ..	4.3	2.4	1.2	1.7	7.2	5.6	7.0	9.4	8.6	11.8	5.9	5.3	10.1	29.2	11.2	70.4
1937 ..	10.1	5.2	1.7	3.3	3.1	2.2	2.8	6.4	6.4	7.7	5.9	4.3	8.1	14.5	10.2	59.1
1938 ..	3.7	2.7	2.2	1.8	1.8	7.1	4.4	12.7	6.7	4.3	13.5	5.6	5.8	26.0	11.1	66.5
			Planting			Growing			Reaping							

From experiences such as these, it is claimed that "best returns of cotton can be looked for "(on light sandy soils in Montserrat) when the "rain falls in increasing amounts during the four "months succeeding the date of planting" . . . . "rising up to about 8 ins. in the fourth month."

..Conclusions: Evidently the preference for an early planting date in Montserrat may partly be determined by the possibility of the occurrence of accumulated nitrate in the soil and by the likelihood of relatively dry weather during the reproductive period in July, August and September, with minimum incidence of pests and diseases. This at best is a "gamble on the weather" and it still remains to be proved whether, with increasing knowledge of the ecology of the cotton crop and by experience gained from the judicious use of artificial and other manures, with due consideration as to soil-type, more dependable yields and better returns could not be obtained in Montserrat with a late sowing date, such as September, as preferred by the St. Vincent cotton planters.

St. Kitts

As far as the writer is aware, no comprehensive experiments with artificial manures have been carried out on cotton in St. Kitts. Most of the cotton soils are *Lithosol* or *Yellow Earth* bordering on Lithosol containing only medium amounts of nitrogen. They would, therefore, be expected generally to respond to nitrogenous manures. The planting date in St. Kitts is March, since the plant is grown as a catch-crop between successive crops of sugar-cane so that, in some instances and in favourable years with regard to dry season rainfall, the soil may contain an appreciable quantity of accumulated nitrate. Only when the content of total nitrogen is relatively high, however, would the amount of nitrate produced be expected to be large enough to meet the needs of a vigorous crop.

The mineral nutrient status of the St. Kitts soils is very variable. Available phosphate is often inadequate; thus, out of 80 determinations recorded in the Annual Reports of the Agricultural Department for 1936 and 1937, 48 were below the provisional limit of adequacy for cotton. Available potash is generally markedly deficient; out of 120 reported cases, 93 lay below the limit of adequacy. The soil samples analysed were obtained from sugar-cane lands but doubtless all or most of the fields are utilised also for growing cotton. Highly beneficial and probably very remunerative results may be expected from the proper use of artificial manures on cotton in St. Kitts and field experiments to test the possibilities are needed.

Nevis

There seem to have been few manurial experiments on cotton carried out in Nevis until recent years. In 1938, and again in 1940, preliminary trials were made (by J. N. W. Niccolls) on *Shoal* soil but the results were inconclusive. In 1941, randomised block experiments were laid down at two different sites on *Shoal* soil. The control-plot soil was chemically analysed at the College. The results of the analyses and the responses obtained to manuring are set out in Table III.

Discussion: Soil composition is very different at the two sites. The second site was recently pasture land with Acacia scrub; the soil here contains abundant nitrogen, phosphate and potash. The first is deficient in all three nutrients. The no-manure plots produced average yields of 1566 and 640 lb. seed cotton per acre, respectively, at the two sites. The maximum yield obtained (with complete manure) at the poor site was 978 lb., an increase of 53 per cent. attributable entirely to manuring with artificials, but the response was not quite statistically significant. The month of sowing was September which is usual for the Island. Germination and early growth were better at the second site but otherwise vegetative development and fruiting were normal with no signs of physiological disturbance. The rainfall was somewhat excessive.

TABLE III: SOILS OF NEVIS: RELATIONSHIP BETWEEN RESULTS OF MANURIAL EXPERIMENTS AND CHEMICAL SOIL DATA. (TOP 6-ins. LAYER)

Control plots	Soil type	Index of text. (I.T.)	C/N ratio	Total N %	Probable nitrate (NO_3-N) ppm.	Avail. phosphate (P_2O_5) ppm.	Avail. potash (K_2O) ppm.	Results of manurial experiments
C.B.1	Shoal	7	13.5	.112	38	34	139	S-A 16% increase ; Super
2	„	10	12.9	.102	35	34	113	15% S-Pot 4%
P. 1	Shoal	14	12.5	.204	69	115	309	S-A no response ; Super
2	„	14	12.8	.217	74	179	310	slight, and S-Pot nil
3	„	12	13.3	.168	57	71	194	

Conclusions: With a late sowing date, an impeded-draining soil under rainy and cloudy weather during the four vegetative months, should not in theory exhibit any serious need for nitrogenous manure, except when it is markedly deficient in total nitrogen. For example, the Shoal soils of Nevis would be expected in general not to require treatment with artificial nitrogenous manure, and where they do, they would be expected to respond in inverse proportion to the nitrogen contents. Low nitrogen content in turn, depends on the degree of erosion which appears to be variable in different parts of the Island. The soil data for the last two experiments in Nevis indicate that the critical nitrogen content for Nevis Shoal is about 0.14 per cent. for the top 6-ins. layer of soil, corresponding with a nitrate incubation value of about 48 p.p.m. NO_3-N; this agrees fairly closely with the conclusions reached earlier in this article. Injudicious and excessive manuring with quick-acting nitrogenous manures, however, might raise nitrate production excessively in the Nevis cotton soils and thus cause physiological disturbance and diminution in yield. Eroded Shoal soil in Nevis, besides being deficient in nitrogen, is likely also to be deficient in available phosphate and available potash, so that phosphatic and potassic manures may be required in suitable proportions to give a "balanced" ratio with nitrogen for maximum yields.

(V) A Biochemical Test for Nitrogen Deficiency

In cases where cotton soils are suspected of shortage of nitrogen, a simple test might be applied which has given useful results in India.* Its value under West Indies conditions cannot at present be gauged, since as far as the writer is aware, the test has not yet been put to critical examination. The procedure is as follows :—

> Six cotton plants are selected at random from a ¼ acre plot and 30 disks are cut out from mature leaves with a punch. The disks are put into a tube with 15 cc. water and kept hot for 2 hours in a boiling water bath. The extract is cooled and 5 drops of an aqueous solution of osmic acid are added (0.1 g. osmic acid, 200 cc. water), followed by 2 drops of dilute sulphuric acid. A dark green or brown coloration denotes the presence of *tannin* which develops in cotton leaves when nitrogen is deficient in the soil. If the extract remains yellow or orange, the nitrogen status of the soil is said to be satisfactory.

* R. H. Dastur and S. Singh, *Indian Journ. Agric. Sci.*, 1944, 14, 5, p. 331.

Summary

1. The fluctuations of nitrate in cotton soils appear to be intimately linked with variations in soil moisture content; they thus depend on the "effective" rainfall. The generalisation that nitrate is likely to accumulate in the rooting zone when the monthly rainfall is less than 2.4 ins. and is probably lost by leaching when it exceeds 4.0 ins. is accepted as a working basis.

2. Consequently, the soil nitrate status in the different British West Indies cotton-growing areas is likely to vary significantly because of their great variability of climate.

3. Cotton plants suffer characteristic physiological disturbances under certain climatic conditions and according to the date of planting. These disturbances may be explained as effects of nitrate fluctuations. They are more marked on soil-types having impeded drainage and on soils containing relatively large amounts of total nitrogen than on free-draining soil-types deficient in nitrogen.

4. Carbon-nitrogen ratio seems generally not to be an important factor deciding nitrate-production in the cotton soils of the British West Indies in which its critical value appears to be about 10.5. This is considerably higher than the critical value for Queensland cotton soils, presumably because of the wetter climate in the West Indies.

5. The nutrient status of typical British West Indies cotton soils, as assessed by a large mass of chemical analytical data, is compared with special regard to available nitrogen, phosphate and potash. Significant differences occur between contrasted soil-types and within each particular soil-type as developed in the different insular areas.

6. The results of manurial experiments on cotton carried out in the past in the British West Indies (mainly St. Vincent and Montserrat) are considered in relation to soil nutrient status and planting date. A close concordance between recorded responses and soil chemical analytical data is indicated, although the efficacy of added manures (especially nitrogenous manures) seems to depend largely on planting date and the subsequent weather.

7. Provisional limits of adequacy have been derived for the purpose of interpreting chemical analytical data for West Indies cotton soils; they are, total nitrogen, 0.12 per cent.; nitrate-nitrogen (incubation) 40 p.p.m.; available (Truog) phosphate, 40 p.p.m. and available (exchangeable) potash, 140 p.p.m. These values are liable to alteration pending further experience; they are meant at present to apply only in a broad and general way.

8. It is suggested that, in planning future manurial experiments on cotton in the British West Indies, soil chemical analysis should be employed as a basis for deciding kinds and quantities of manures to be added and for interpreting yield results and physiological growth phenomena.

9. A simple biochemical test for nitrogen shortage in cotton soils is outlined.

Acknowledgments: The writer is indebted to Mr. J. B. Hutchinson, late Cotton Adviser, E.C.G.C. for inspiration without which this research would not have been undertaken. He is grateful also to Mr. J. V. Lochrie, present Cotton Adviser, for useful suggestions and for reading the proof of this article. The first field tests of the possible value of chemical soil analysis in the formulation and interpretation of manurial experiments on cotton in the British West Indies was undertaken in Montserrat by Mr. W. R. E. Nanton (formerly Diploma Student at the College) in consultation with Mr. Hutchinson, and to him is due the credit for their success.

Appendix

Corroborative Evidence from Nitrification Data for Cotton Soils in the Sudan Gezira

The nitrate status of the cotton soils of the Sudan Gezira has been described in a recent article* from which some interesting comparisons with conditions in the British West Indies may be drawn. In the Sudan, yields of cotton can be greatly increased by artificial nitrogenous manures. Calcium nitrate has proved superior to ammonium sulphate, because the climate is hot and dry (irrigation is practised) and the soil is highly alkaline, (pH 9.0-9.5) so that added ammonium sulphate is partially but slowly deammoniated, thus causing considerable loss of nitrogen. A marked positive correlation between the nitrate level in the soil and the yield of cotton has been demonstrated.

The soil-type is an impeded-draining heavy alluvial clay which is markedly saline below 2 feet. The total nitrogen content of the upper 2 feet of soil is stated to be 0.03 per cent. That of the top 6-ins. is not given, but by analogy with heavy soils in the West Indies, it should be around 0.05 per cent. which is extremely low according to West Indian standards. The nitrate-nitrogen content of the top foot of soil in the Gezira Research Farm is stated to vary from 2 to 20 p.p.m. and in the cotton fields under irrigation from 5 to 20 p.p.m. When incubated for five weeks under ideal conditions in the laboratory, values were obtained for nitrate-nitrogen of typical Gezira cotton soils lying between 5 and 40 p.p.m. for the top 6 ins. layer, highest values being given by samples from land that had been rested for two years. The total nitrogen content of these samples lay between 0.023 and 0.025 per cent., so that the soils were capable of nitrifying between 2 and 13 per cent. of their total nitrogen content. The average value for nitrifying efficiency quoted for Gezira soils with 4 weeks' incubation is 5 per cent. of their nitrogen contents. For West Indies and Queensland soils it is 3.4 per cent.

Some values for nitrifying efficiency for soils of other (arid) regions are also quoted, for example:

U.S.A.: California 5—10%; Utah 3%; Washington 1—5%; Texas 5—10%; Kansas 3%
South Africa: 5%. *India*: 1—3—6% *Mean*: 5%.

Rapid nitrification of ammonium sulphate takes place when it is added to Gezira soils having a wide range of moisture content; 23 per cent. of the nitrogen thus supplied was nitrified in laboratory trials in the first 7 days. It is deduced that at least 40 per cent. of the nitrogen applied in the field as ammonium sulphate manure at sowing time is nitrified within a fortnight. The size of a standard dressing is 200 lb. per acre, equivalent to 23 p.p.m. of nitrate in the top 6 ins. layer, and 40 per cent. of this, i.e., 9 p.p.m., represents a large increase in nitrate-nitrogen in a soil which normally contains up to 20 p.p.m. of nitrate-nitrogen. Comparison with laboratory results for typical cotton soils examined at the College* shows that they are capable of nitrifying between 18 and 50 per cent. of added ammonium sulphate under identical laboratory conditions as those observed in the Sudan experiments, so that, in the field, ammonium sulphate added as manure should be effectively nitrified within 2 to 6 weeks from the date of application, provided the absorptive capacity (base exchange status) of the soil is sufficiently high to fix all the ammonium-ion so that it is not lost by leaching.

The nitrification of organic nitrogenous materials proceeds normally in Gezira soil. The soil is very sensitive to additions of carbohydrates such as starch or sucrose which reduce the natural nitrate content of the soil to negligible proportions when supplied in laboratory cultures in quantities equivalent to about one ton of cellulosic organic matter per acre. It should be noted, however, that the original organic matter content of Gezira soil is very low so that the fate of added organic nitrogen is decided more by the nature of the material added than would be the case with soils already containing considerable amounts of organic matter having high carbon-nitrogen ratio. It was found that, with cotton-seed meal used as nitrogenous manure, nitrate production depended, not only on the total amount of nitrogen added, but

* Nitrification in Sudan Gezira Soil. T. N. Jewitt, *Journ. Agric. Sci.*, 1945, 35 pp. 264-271.

* The Agricultural Soils of St. Vincent; F. Hardy, C. K. Robinson and G. Rodrigues; I.C.T.A., 1934, p. 28.

also on soil moisture content, being reduced to zero at 70 per cent. moisture content. On the other hand, at low moisture contents heavy growths of fungal mycelia developed as the material decomposed. This is believed to immobilise large quantities of nitrate. By contrast, the nitrification of added ammonium sulphate was found to be much less influenced by soil moisture conditions, being appreciable even at 70 per cent. moisture content, as well as over a very wide range below.

These findings may explain many of the failures recorded in manurial experiments in the British West Indies where cotton-seed meal and other organic nitrogenous manures have been repeatedly tried without much success. The wider use of ammonium sulphate and other inorganic nitrogenous manures, skilfully applied, either alone or in conjunction with organic materials, would thus seem to offer great future possibilities in the cotton industry of the British West Indies.

MINERAL CONTENT AND YIELD OF GRASSES IN THE WET TROPICS*

Three papers by J. L. Schofield have recently appeared in *The Queensland Journal of Agricultural Science* dealing with investigations into the yield and chemical composition of pasture grasses conducted at the Bureau of Tropical Agriculture in coastal northern Queensland. The first paper (1) dealt with the yield aspect of the work, and data on the protein content of the grasses were presented in the second paper (2). The results presented in the third paper (3) which deal with the lime and phosphoric acid of various grasses, as influenced by productivity period, frequency of cutting and species are summarized as follows :

The lime and phosphoric acid content of 19 grasses was determined under monthly, two-monthly and three-monthly cutting systems over periods of between one and two years.

Under monthly cutting there is during the first 12 months a negative correlation between lime content and rainfall and a positive correlation between phosphoric acid content and rainfall.

The four lime-rich grasses under monthly cutting include two varieties and one strain of *Panicum maximum*, and two varieties of *Panicum maximum* are among the four grasses with the highest mean phosphoric acid content for the first 12 months.

The same pattern of lime content is shown under two-monthly and three-monthly cutting as under monthly cutting. Phosphoric acid content is dependent on the stage of maturity.

The ratio of phosphoric acid and lime equivalents is satisfactory for some grasses but for others is much narrower or wider than the standard of 1.5 : 1 adopted for purposes of comparison.

The outstanding conclusion to be drawn from the investigation is that there are marked differences between the various species examined in both the content and the yield of lime and phosphoric acid. Under the same soil and climatic conditions, the mean lime content of 19 grasses for 12 months under a system of three-monthly cutting varied from a maximum of 1.042 per cent. (*Panicum maximum* No. 3820) to a minimum of 0.369 per cent. (*Hyparrhenia aucta*), and the yield from 184 lb. (*Panicum maximum* No. 3820) to 40 lb. lime per acre (*Paspalum dilatatum*). The corresponding mean phosphoric acid content ranged from 0.791 per cent. (*Cenchrus ciliaris*) to 0.218 per cent. (*Hyparrhenia aucta*), and the yield from 109 lbs. (*Brachiaria decumbens*) to 33 lb. phosphoric acid per acre (*Paspalum dilatatum*).

These results show that, where supplementary mineral foods are not to be supplied, care must be exercised in selecting pasture or fodder grasses for use in the tropics. Certain grasses, particularly some types of Guinea grass, are lime-rich and approach in value the figure of 1.004 per cent. given by Godden (in Elliot *et al*, 1926) for an English cultivated pasture. Two lime-rich grasses — *Panicum maximum* vars. *typica* and *coloratum*—deserve special mention. Without fertilizer application and under three-monthly cutting, their mean lime contents for 12 months were 0.943 per cent., and their yield of lime 179 lb. and 73 lb. per acre respectively. These two grasses are hardy, vigorous and aggressive and the variety *coloratum* is particularly palatable : both deserve to be given widespread recognition as valuable lime-rich fodder grasses capable of thriving on acid soils. The small quantity of 73 lb. of lime per acre per annum given above for *Panicum maximum* var. *coloratum* is for the three-monthly cutting rotation, under which only 15.8 tons of green-matter per acre were produced : under a two-monthly rotation the yield of green-matter was 24.1 tons per acre (Schofield, 1944).

Among the grasses poor in lime under the conditions of the experiment are *Pennisetum clandestinum*, *Melinis minutiflora*, *Paspalum dilatatum* and *Chloris gayana* Nos. 6585 and 6586. It has been reported from the West Indies that *Melinis minutiflora* is very poor in minerals and the suggestion made that the extension in the use of this grass should be confined to areas which will not grow *Panicum maximum* satisfactorily.

The phosphoric acid content also shows wide variation according to the species. Even under a system of three-monthly cutting (where values tend to be low due to the influence of maturity on phosphoric acid content) several grasses, including *Cenchrus ciliaris*, *Pennisetum clandestinum* and *Panicum maximum* var. *trichoglums*, exceed a mean value of 0.7 per cent. for the 12 months. At the other extreme are *Chloris gayana* Nos. 6585 and 6586, *Paspalum dilatatum* and *Brachiaria decumbens*, all

* Abstracted from *The Queensland Journal of Agricultural Science*, Vol. 3, 44-79.

with means of less than 0.4 per cent. Actually *Brachiaria decumbens* produced the highest yield of 109 lb. of phosphoric acid per acre per annum, but this was due to its extremely high yield of herbage.

Summed up, the results of the pasture investigations reported in the series of papers of which this is the third indicate that grasses are available which are suitable for pasture purposes on the alluvial schist soils of coastal tropical Queensland. While some are in themselves satisfactory with respect to yield of dry-matter and to content of protein, phosphoric acid and lime, others will require to be grown in association with a legume. Investigations have shown (Schofield, 1941, 1945a) that suitable legumes are available.

(1) Schofield, J.L. 1944. The effects of season and frequency of cutting on the productivity of various grasses under coastal conditions in northern Queensland. *Qld. J. Agric.* Sci., I, 1-58.

(2) Schofield, J.L. 1945. Protein content and yield of grasses in the wet tropics as influenced by seasonal productivity frequency of cutting and species. *Qld. J. Agric. Sci.* 2, 209-43.

(3) Schofield, J.L. 1946. Mineral content and yield of grasses in the wet tropics as influenced by seasonal productivity, frequency of cutting and species. *Qld. J. Agric. Sci.* 3, 44-79.

REVIEWS

Colonial Agricultural Production

Colonial Agricultural Production: The Contribution Made by Native Peasants and Foreign Enterprise. By Sir Alan Pim. Pp. 190. Issued under the auspices of the Royal Institute of International Affairs. London: Oxford University Press, 1946. Price 10s. 6d.

Sir Alan Pim has selected a number of tropical territorities, both British and foreign dependencies, for his study of agricultural production of peasant and plantation. The Netherlands East Indies, Malaya, Fiji, Ceylon, Mauritius, the West Indies, West, Central and East African dependencies all come under his authoritative examination. Apart from the analysis of plantation and peasant production this book contains a wealth of information on the agriculture and economics of a large number of tropical countries; the work includes a full index which increases its value as a reference book on these tropical countries and the commodities they produce.

The main purpose of the work is, however, to compare peasant and plantation agriculture, the contribution which each makes and has made to the total agricultural production; and the efficiency, stability and suitability of each to the territory concerned. The contrast briefly is this: the plantation by importing capital and management is at an advantage over the peasant from the technical point of view; the peasant has the advantage of smaller overhead costs and a greater elasticity as to labour earnings. The technical inefficiency of the peasant is evident not only in current production such as inadequate and sometimes unintelligent cultivation, poor marketing organisation, etc., but also in long term production by his inability to accumulate capital and conserve his soil. The problems of credit and land tenure are therefore rightly considered for almost every territory examined.

From the technical point of view the advantages of the large strongly-financed plantation outweigh those of the peasant system for almost every export product. If the main consideration in developing colonial dependencies were still supplying metropolitan countries with a bountiful, cheap supply of tropical products which they themselves cannot produce, every measure would be taken to facilitate the expansion of the plantation system. Such a policy does not of necessity imply exploitation of the indigenous populations; the technical efficiency of the plantation may well make it possible (as in the case of sugar cane in Hawaii) to raise the standard of living of the local population employed mainly as labourers above not only their previous near subsistence level, but often well above the level they could achieve as independent and unregimented peasants.

Social and political considerations (mainly) make it desirable to foster peasant agriculture. Sir Alan's book makes it increasingly clear to the reader as territory after territory is discussed, that without some forms of compulsion or regimentation or very firm guidance, few peasants are capable of producing at a permanent level of efficiency which will yield them a standard of living much above subsistence. Compulsion may take the form of Government regulation or the need of immediate processing of crops (when the processing agent can enforce standards he may require) or the necessity for irrigation, when the irrigation authority can exercise similar control. Without these goals the peasant is always liable to sink into a morass of debt in which he is incapable of farming efficiently. It appears that in non-British territories where compulsion of one kind or another has remained from an older and less humane Colonial period, the native population is on the whole better off than in many British territories in which compulsion of every kind has been shunned as an evil of itself. It has not evidently been accepted by British authorities that the professional money lender curtails the peasant's liberty far more stringently than (for instance) a Government ordinance compelling all peasants to contribute to a co-operative savings bank.

This book is not confined to a comparison merely of the large company plantation and the peasant proprietor; there is recurrent mention of the small family planter. This type appears in the past to have incorporated most of the disadvantages of both peasant and company owned plantation with few of the advantages of either. All over the tropical world the small planter has been, or is being superseded by peasant or company owned plantation. The family planter, indeed, was the pioneer who opened

up new country and reaped bountiful profits until the territory was well developed and the product firmly established. It appears that the family estate is outmoded and is likely to disappear as a type of farming from tropical agriculture.

Nevertheless there would be economic and social advantages to be gained by a revival of a modified family planter system. The advantages are that such planters (not necessarily European) could provide a middle class which is so sadly lacking in tropical communities; they could be a far more potent educative influence to peasant and labourer than the large plantation on account of their smaller scale of operation; because their family fortunes are bound up with one estate, these planters if firmly established could be a great stabilising and cohesive influence in the community. The feasibility of the revival of the family estate depends on the technical advances in more intensive methods of production under tropical conditions, especially of mixed farming which requires detailed and diverse management and cannot be so efficiently pursued on a large scale as on a medium scale. Large, easy profits of the small plantation are a thing of the past, but it is possible that a mixed farming technique may advance to the stage of yielding the small planter profits sufficient to maintain educated, if hard working, successors to the family estate.

It can be seen that this book is provocative of thought beyond the simple issue of peasant and company owned plantation. It cannot fail to raise in the reader's mind the whole issue of the social and economic welfare of the millions of people who live in tropical dependencies. As such the book is most timely in having the power to stimulate all who will be entrusted with the reorganisation that will inevitably be necessary in the post war period.

A.L.J.

* * *

Principles of Agriculture Botany

Principles of Agricultural Botany. By Alexander Nelson, B.Sc., Ph.D., N.D.A. (Pp. 556, 17 Plates in colour, 128 half-tone plates, 182 illustrations in the text). London: Thomas Nelson and Sons, 1946. Price 35s.

The author of any text-book on agricultural botany is faced with a difficult problem: he must avoid being too "theoretical" but must also avoid (what is probably the greater evil) too facile a generalisation, too great a simplification in the interests of elementary teaching of problems and topics that have intrinsic botanical difficulty. Dr. Nelson is clearly aware of this and that his text does not completely solve the problem is perhaps not entirely his fault.

The field covered is a wide one, embracing the morphology and anatomy of the flowering plants, physiology, pathology, etc., and heredity, evolution and classification. Throughout, emphasis is placed on agricultural applications of the subject and the more purely agricultural sections are excellent (e.g., Pasture, (Ch. 21), Weeds (Ch. 22) and Seeds (pp. 213-229). Another admirable feature of the book is the use and citation of recent work on many topics, for instance: herbicides, mineral deficiencies, inorganic nutrition. The plates (of which there are 17 in colour and 128 in black and white) are of consistently high quality and are almost all well-chosen; they make this undoubtedly the best illustrated text-book of botany that the reviewer has seen and may well serve as a model in this connection. The line drawings in the text are mostly good though some appear unnecessary and a few are inaccurate (e.g., Figs. 17 and 66).

On the debit side, it may be said that the text suffers from an excessive sub-division and a somewhat jerky, incoherent style. Furthermore, there is some careless and even seriously teleological writing and there are several inaccuracies and contradictions. The following points are noted in the hope that they may be corrected in the later editions of the work: "advanced" (p. 26): "amorphous mass of the nucleus" (p. 34): "the Benefits derived from Sexual Reproduction" (pp. 144-5): the implication (pp. 536-7) that the flowering plants have evolved from the "lowly moss" by a series of stages involving the reduction of the gametophyte: "In the Thallophyta ..... the sexual processes are obscure and primitive" (p. 537): the use of nouns as adjectives, e.g. Dicotyledon Leaf (p. 58, etc.): the use of new and unrecognised terms, e.g. "Recession" (p. 512); the accounts of meiosis (pp. 159-61, Fig. 66), chiasmata (p. 518, Fig. 178) and the statement (p. 517) that "Free segregation is not possible when the different gene pairs are in the same chromosome pair". The fourth and last section (Heredity, Evolution and Classification) is sufficiently sketchy to be quite misleading and the failure to use or even to mention the existence of scientific binomial names until this section is most undesirable. While many native names for plants have admittedly reasonably exact connotations, they have at best a limited circulation and it is surely ridiculous to use such terms as "various-leaved Fescue" (p. 132) which can certainly not be justified by the excuse that "it's easier for the practical farmer". And such a cavalier treatment of botanical nomenclature accords ill with the admirable sentiments expressed in the closing paragraphs of the introduction, To the Student.

The book is excellently printed and produced, the plates deserving especial praise. There are extremely few typographical errors (e.g. "mieosis", p. 518 and "Spermophyta", p. 534). Clearly, a great deal of care has gone into its production and the publishers are much to be congratulated on a fine piece of work.

N.W.S.

ERRATA OCTOBER ISSUE

Page 190, 2nd column, para. 4 line 1. For 50°F read 5°F.

Page 191, 2nd column para. 4 line 7. For "applicable" read "inapplicable"

Page 192, 2nd column, para. 2 line 2. For "broblems" read "problems"

Page 192, 2nd column para. 2 delete line 17.

Page 193, 2nd column under references, ref. 10. Add *Tropical Agriculture*, Vol. 16, pp. 200-202, 1939.

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Grapefruit Storage Experiments

Two treatments tried in grapefruit storage experiments were: waxing alone (intended primarily to obviate shrinkage), and waxing after immersion in a 5% borax solution. The waxed fruit showed substantially less waste than the untreated fruit, presumably because the waxing process removes a number of mould spores from the fruit and prevents their making direct contact with the rind. The boraxed fruit showed less waste after 11 weeks' storage than the non-boraxed at 5 weeks, and the fruit in the two groups held from 13 to 14 weeks showed a loss of 12.7% for the boraxed treatment at 14 weeks, compared with 34.7% for non-boraxed fruit at 13 weeks.

(*Citrus News*, 20: 143, *Hort. Abstracts*, 16, 137, 1946).

* * *

Spraying Citrus Trees for Mineral Deficiencies

Some South African soils have inadequate supplies of zinc, magnesium, copper and manganese for the needs of citrus trees; deficiency of zinc occurs in many areas. Symptoms are smallness and mottling of the leaves and, in severe cases die-back of the trees. As soon as slight mottling appears a foliage spray of 4 lb. of zinc sulphate + 2 lb. of hydrated lime in 100 gallons of water should be applied and used regularly once every two years. Applications to the soil are usually uneconomical and may cause severe injury to the trees. If deficiency is acute 4-6 gallons of a spray containing 10 lb. of zinc sulphate + 5 lb. of hydrated lime in 100 gallons of water should be applied to each tree. Sprays may be applied at any time of the year, but quickest results are obtained just before the growth flush; or trees may be sprayed just after fruit has been harvested. Heavy rates of application have no greater effect than light ones. Deficiency of manganese, magnesium and copper are less common. Manganese and magnesium deficiency causes chlorosis and copper deficiency results in the formation of gum pockets in the fruit and young twigs. Applications of foliage sprays give quicker results than applications to the soil. (*Soils and Fertilizers*, 9, 235, 1946).

* * *

Relationship Between Rainfall and Richness of Sugar Cane

It is well recognized that the normal development of the sugar cane requires an adequate supply of moisture. What seems to be an anomalous situation in Cuba is discussed. In certain zones the cane produces its maximum yield of sugar under relatively dry conditions in October and the following months; in case of an increase of precipitation during this period, the sugar content of the cane is reduced. On the other hand, there are zones where this condition is reversed; that is, the cane gives a greater yield when the rains are well distributed from October on. The cause of this marked difference between the cane-growing zones is traced to the different abilities of the soils of these zones to retain moisture. Data are presented to show the effect of rain during the harvest over a period of 12 years at two factories; in one case, abundant rains in February did not decrease the yield, whereas in March and April the rains markedly reduced the yield. In the other case, February was rather dry and the yields were low; when there was much rain in March the yield tended to increase, but in April the tendency was toward low yields. Evidently the matter requires further study, but the fact remains that in given cases the sugar content of the cane is in one way or another intimately connected with the amount of rain, character of the soil, and cultural operations. (*Sugar*, 41, 49, 1946.)

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When to Plough a Green Manuring Crop

The common practice of ploughing down green manure in full green pod before the end of the rains leads to serious losses in plant nutrients, especially N, in the green manure, through leaching by rain to the subsoil. A series of experiments with sunhemp and maize has been made at the Salisbury Experiment Station and showed the later ploughing down of the sunhemp (from mid-April to mid-May) enables the decay of the more mature green crop to extend over the whole of the growing season of the following maize and results in higher yields. Early planting of maize normally results in heavier grain yields since the soluble nitrates from the green crops are available before they can be washed down into the subsoil out of reach of the young maize roots.

The later the green crop is ploughed the more unrotted trash will remain in the top few inches of soil when the following crop is due to be planted, and with mechanical planting dates must be adjusted according to the rains. (*Soils and Fertilizers*, 9, 208, 1946.)

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I.C.I. and India's Fertilizers

When the Government of India decided that a large-scale nitrogen fertilizer industry was necessary to increase India's self-sufficiency in food, it went to Imperial Chemical Industries, Ltd., for expert technical advice, which was quickly given. A special mission went out and its findings have formed the basis of the immense project now under way in Bihar province. This will eventually provide India with one of the largest synthetic fertilizer factories in the world. It will have a capacity of 350,000 tons of ammonium sulphate per annum, and some of the plant has been shipped already. (*Jour. Soc. Chem. Indus.*, 37, 344, 1946).